TECHNICAL MEMORANDUM

NO. 5

A METEOROLOGICAL MODEL TO AID IN THE DETECTION OF WINTERKILL

FOR CROP CONDITION ASSESSMENT PROGRAM

TM-5

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREIGN AGRICULTURAL SERVICE

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A METEOROLOGICAL MODEL TO AID IN THE DETECTION OF WINTERKILL	FIRST ISSUE

Approved By:

Jimmy D. Murphy
Acting Director, Crop Condition Assessment Division

1. REASON FOR ISSUANCE

   Discuss the development of a model which gives an early indication of possible winterkill damage in winter wheat.

2. COVERAGE

   The meteorological parameters associated with winterkill are discussed. A description of the model software programs is given along with some preliminary results.

3. ACKNOWLEDGEMENT

a. Prepared by: Frank Ravet — Frank W. Ravet — Date: 1/24/79

George A. May — George A. May — Date: 1/24/79

b. Collaborative plot and field data for Montana provided by SEA, Dr. A. Black with agronomic assessment and consultation by Dr. G. Boatwright, SEA and Dr. Joseph H. Caprio, Montana State University.

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PART 1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this paper is to discuss an indicator model that gives timely information in the detection of possible winter wheat kill areas, extent of the kill, and severity. A brief synopsis of the winterkill process is also given.

1.2 SITUATION

A major task of the Crop Condition Assessment Division Foreign Agricultural Service, is to detect and assess adverse conditions that affect a crops growth and production. Of major importance is the winterkill that occurs in winter wheat. To support this activity an indicator model was developed to alert a crop analyst of a potential problem area. The model utilizes meteorological data, because, it is generally available much sooner than Landsat data, and provides daily data versus the eighteen day interval data from Landsat. This model eliminates the spending of time and resources in analyzing data over all wheat areas susceptible to winterkill and allows these resources to concentrate on those areas which the model indicates have high probability that winterkill has occurred. After a potential winterkill area has been identified, an analyst can assess the condition using meteorological, Landsat, and ancillary data. This model is not intended as a stand-alone system, but rather, an indicator to a crop analyst to initiate an investigation of the area.

PART 2.0 WINTERKILL PROCESS

2.1 HARDENING AND TEMPERATURE EFFECTS

Winterkill is the loss or damage of the plant due to physiological changes resulting from low temperatures and associated physical factors. Some of the primary causes of winterkill are: freezing, heaving, smothering, and physiological drought.

A wheat plant's winter hardiness plays a vital role in minimizing damage and destruction during the cold season. Winter hardiness is dependent on wheat varieties, autumn vegetative growth, and the ability of the plant to harden.

The first phase of hardening is development of frost resistance. This occurs during sunny days with a maximum mean daily air temperature around 12°C and a drop to around 0°C at night (2,3). These conditions are favorable for the concentration of sugars, amino nitrogen, and amide nitrogen in the tissues, which lower the freezing point of the plant.

The second phase of hardening occurs during frost periods and is independent of sunlight. In temperatures ranging from -2 to 5°C the protoplasm undergoes restructuring with the rearrangement of plasma and cell dehydration in the plant (2,4). When plants enter winter dormancy the starches disappear and various types of sugars are accumulated.

The tillering node of a wheat plant is the most vital organ. Death of this node will result in death of the plant. The node will have varying resistance to low temperatures because of the changing weather conditions during the first and second hardening phases. This variation is shown in Table 1 for wheat grown in the Great Plains of U.S.A. and northern areas of Russia.

A plant's winter hardiness does not remain constant throughout the cold season. Low temperature resistance increases at the beginning of winter, in conjunction with the hardening process. At mid-winter the resistance reaches a maximum and then starts declining. Therefore, cold temperatures in late winter or early spring can be extremely harmful to a wheat crop. The duration of low temperatures also plays a role in winterkill. A single day of low temperature may have minor effect on a wheat plant, but if low temperatures persist for three to four days, winterkill will be more severe.

2.2 ROLE OF SNOW COVER

Snow cover is an important factor in the wintering of wheat. The ability of snow to insulate is approximately 10 times that of mineral soil (2). An accumulation of snow protects a wheat plant and its tillering node from cold air temperatures. A relationship between

snow depth and soil/air temperature has been established and reported in the literature (2). The differences between the air temperature and soil temperature at the tillering node, under various snow depths, are given in Table 2.

It can be seen from Table 2 that as snow depth increases the temperature difference does not increase proportionally. Therefore, an extremely thick snow cover is not necessary to protect a crop from severely cold temperatures.

An uneven snow cover over an area will have differing effects on the winter wheat crop. High winds, uneven terrain, wind breaks and other factors cause variations in snow depth. Russian scientists have gathered data which allow them to predict the percentage of actual depths of snow given a reported snow cover (Table 3). This type of information is needed when developing an indicator model for winterkill.

PART 3.0 WINTERKILL INDICATOR MODEL

3.1 STRUCTURE OF MODEL

The Winterkill Indicator Model was developed on a DEC 11/70 computer using the FORTRAN IV language. The main inputs to the model are daily minimum and maximum temperatures, snow cover, and control data.

The model consists of three parts: control program, meteorological interface program, and winterkill indicator program. The control program is used to regulate the sequence of program calls, and the input/output interface. Inputs to the control program are a meteorological data set name, starting date, and stop date. This program provides a tabular listing, by stations, of the meteorological data and error condition.

The meteorological interface program is used to read station data from the meteorological data set for a specific time. It also converts all information to metric, if necessary, and provides some error checking and recovery.

3.2 MODEL PARAMETERS

The winterkill indicator program is the main subprogram. This program calculates the hardness factors, converts station reported snow cover to percent of field cover at various depths, and then calculates the percentage of the wheat nodes that lay in a zone of possible winter damage.

The indicator model contains six hardening stages. The first two occur in the autumn, between mid-October and mid-December. Stages three, four, and five are the winter hardness stages that occur after mid-November. Hardness stage one is reached if for five days the temperature drops below 0°C and rises to approximately 12°C. The days do not have to be consecutive. Stage two occurs if, after reaching stage one, the temperature drops below -5°C for a duration of four days. Hardness stages three, four and five are established as follows: If no autumn hardening occurred, the winter hardness is considered poor and set at stage 3 in the model; if hardness stage one was reached, but stage two was not, winter hardness stage 4 (moderate hardening has occured) is set; if fall stages one and two are both reached, then winter hardness is good and stage 5 is set in the model.

In the indicator model the critical temperatures for possible winterkill are based on these hardness stages (Table 4). These temperatures are determined at the tillering mode (3 cm) and the insulating factor of snow and soil (Table 2) is used to adjust the reported minimum air temperatures to soil temperatues at the node. Reported station snow cover is used in a table look up to determine the areal distribution of the snow (Table 3). Using these factors the model calculates the percentage of tillering nodes that lay

in a zone where the temperature dropped to the killing level for each day. Note however, that the possible killing condition must exist for several days for actual winter wheat damage to occur. Therefore, a single day indicator is not important. It must be set for three to four days to become significant.

3.3 PRELIMINARY TEST RESULTS

Preliminary tests of the model have been run using 1978 metorological station data over areas of known winterkill in Montana and North Dakota. Also included in the data set were areas of borderline conditions that were close to winterkill areas. An area of reported severe winterkill was reported in eastern Montana. The Glasgow, Montana station is located on the west side of this area and the Williston, North Dakota station is on the east side. On-site ground observations estimated an 80 to 90% kill in the area. Analysis of early spring Landsat data showed replanting of many fields in the area, indicating that the ground observations were accurate. As can be seen in Table 5, the model predicted heavy damage at both Glasgow and Williston for several consecutive days in late January and the first part of February. Damage also occurred during the first few days of March.

Another area of indicated damage was in the Havre area. Ground observations during the spring indicated that the wheat emerged from the winter in a "mottled" condition. This "mottled" appearance is generally due to some winter damage to the wheat. In this instance the damage was not severe and the wheat recovered. The results given in Table 5 show that the model gave a indication of this condition with a low percentage of kill for three days.

3.4 FUTURE TESTS

The model will be run in 1979 over most of the Great Plains and some Russian stations to aid in the determination of winterkill. Indications from the model will be investigated using Landsat data and ground observation, where possible. This large area test should help validate the model, if winterkill conditions are present during the 1978/79 winter.

PART 4.0 CONCLUSIONS

4.1 SUMMARY

A Winterkill Indicator Model was developed to support the Crop Condition Assessment Division, Foreign Agricultural Service. This model alerts a crop analyst of possible winter wheat kill areas, severity, and areal extent of the kill. The model was tested over Montana and North Dakota using 1978 meteorological data. Known areas of winterkill were identified before conducting the test. The model predicted severe damage in these areas. The model also indicated no damage in areas that were identified as having no winterkill. Further testing of this model will be conducted during 1979.

The model only attempts to predict winterkill due to extreme cold. It does not consider other causes of winterkill such as mechanical damage due to heaving, damage due to insufficient moisture, smothering, etc. Some of these factors maybe included in future model improvements.

PART 5.0 REFERENCES

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2. Kulik, M.S. and V.V. Sinekhchikov. 1966. Lectures on Agricultural Meteorology. Leningrad, Russia. pp. 210-226.

3 Margin, J.H. and W.H. Leonard. 1967. Principles of Field Crop Production. The MacMillan Company, U.S.A. pp. 402-403.

4. TIME Study Initial Report: Results of OERS Portfolio Development. 1978. General Electric Space Division. NASA Contract #NAS5-23412, MOD 149. pp 4-27 to 4-42.

TABLE 1

CRITICAL TEMPERATURES (C°) OF WINTER WHEAT

UNDER DIFFERENT HARDENING CONDITIONS

		WELL-HARDENED	MODERATELY HARDENED	LESS HARDENED
*	Montana, U.S.A.	-20°	--	-16°
**	Ukraine, Northern Caucasus, White Russia and northwestern oblasts	-19°	-17	-15°

* Taken from Reference 1

** Taken from Reference 2

TABLE 2

*DIFFERENCE BETWEEN MINIMUM AIR TEMPERATURE

AND SOIL TEMPERATURE UNDER VARIOUS SNOW DEPTHS

Snow Cover (CM)	0	3	5	10	15	20	25	30	60
Tem. Difference (°C)	4.0	5.8	6.5	9.0	11.8	13.3	14.1	15.2	17.0

*Taken from Reference 2

TABLE 3

PERCENT FIELD DISTRIBUTION OF ACTUAL SNOW
DEPTH BASED ON REPORTED SNOW COVER DEPTH

REPORTED DEPTH (cm)	ACTUAL DEPTH (cm)								
	0	1-3	4-6	7-10	11-15	16-20	21-30	31-50	51-80
	% FIELD DISTRIBUTION								
1	70	24	5	1	-	-	-	-	-
2	46	33	17	4	-	-	-	-	-
3	27	38	25	9	1	-	-	-	-
4	18	30	36	13	3	-	-	-	-
5	10	25	39	21	5	-	-	-	-
6	7	19	34	29	10	1	-	-	-
7	5	16	30	35	12	2	-	-	-
8	2	11	25	41	15	6	-	-	-
9	2	7	18	42	23	7	1	-	-
10	1	7	14	38	28	9	3	-	-
11	1	4	12	35	31	13	4	-	-
12	1	3	9	29	38	16	4	-	-
13	-	3	7	24	37	19	9	1	-
14	-	2	6	21	35	23	11	2	-
15	-	2	5	17	33	27	14	2	-
16	-	2	4	14	29	29	19	2	-
17	-	1	4	13	25	30	23	3	-
18	-	-	4	10	23	31	26	4	-
19	-	-	2	9	21	30	32	6	-
20	-	-	2	8	19	28	33	6	-
21-30	-	-	1	3	9	21	44	10	1
31-50	-	-	-	-	1	5	25	21	6

TABLE 4

TEMPERATURE AT TILLERING NODE FORMATION* THAT WILL KILL PLANT UNDER DIFFERENT HARDENING STAGES.

HARDENING	MODEL STAGE	TEMPERATURE C
No fall hardening	0	-7^{0}
Minimal fall hardening	1	-10^{0}
Full fall hardened	2	$-10, -13^{0}$
Poor winter hardness	3	$-14, -16^{0}$
Moderate winter hardness	4	$-16, -18^{0}$
Good winter hardness	5	$-18, -20^{0}$

THREE DAYS OF SUSTAINED LOW TEMPERATURES ARE SUFFICIENT TO KILL PLANT.

STAGES ARE NOT NECESSARILY SUCCESSIVE.

*3 cm

STATION	DATE	% PROBABLE KILL	NUMBER OF CONTINUOUS DAYS	MINIMUM TEMPERATURE C°	SNOW COVER CM
WILLISTON	1/19/78	100.00	1	-30.7	12
	1/20/78	13.00	2	-21.0	12
	1/27/78	13.00	1	-21.2	12
	1/28/78	100.00	2	-27.3	10
	1/29/78	100.00	3	-29.0	10
	1/30/78	22.00	4	-19.6	10
	1/31/78	88.00	5	-26.2	10
	2/1/78	22.00	6	-21.8	10
	2/2/78	100.00	7	-27.9	10
	2/15/78	24.00	1	-24.6	15
	2/16/78	7.00	2	-21.2	15
	2/17/78	24.00	3	-24.0	15
	2/18/78	24.00	4	-22.3	15
	2/26/78	13.00	1	-21.3	12
	2/27/78	13.00	2	-21.8	12
	2/28/78	13.00	3	-20.7	12
	3/1/78	13.00	4	-20.7	12
	3/3/78	24.00	1	-24.6	15
	3/4/78	57.00	2	-25.7	15
	3/5/78	24.00	3	-24.0	15
	3/6/78	24.00	4	-22.3	15
GLASGOW	1/19/78	43.00	1	-25.7	17
	1/29/78	5.00	2	-20.7	17
	1/21/78	5.00	3	-21.8	17
	1/25/78	18.00	1	-22.3	17
	1/28/78	76.00	1	-27.3	17
	1/29/78	18.00	2	-22.9	17
	1/30/78	5.00	3	-21.8	17
	1/31/78	76.00	4	-28.5	17
	2/1/78	68.00	5	-28.5	20
	2/2/78	29.00	6	-27.7	20
	2/27/78	5.00	1	-19.6	17
	3/3/78	29.00	1	-26.2	20
	3/4/78	62.00	2	-27.9	20
	3/5/78	10.00	3	-23.5	20

TABLE 5

WINTERKILL INDICATOR MODEL RESULTS

STATION	DATE	% PROBABLE KILL	NUMBER OF CONTINUOUS DAYS	MINIMUM TEMPERATURE C°	SNOW COVER CM
HAVRE	1/30/78	5.00	1	-21.6	17
	3/3/78	13.00	1	-27.7	22
	3/5/78	10.00	1	-25.5	20
	1/30/78	54.00	1	-31.0	37
	1/31/78	54.00	2	-31.0	37
	2/1/78	31.00	3	-29.3	40
BOZEMAN	1/19/78	13.00	1	-26.7	17
	3/3/78	13.00	1	-28.9	25
CUT BANK	1/30/78	54.00	1	-31.7	32
	2/14/78	54.00	1	-30.6	45
	3/2/78	34.00	1	-28.9	22
	3/3/78	89.00	2	-32.2	22

TABLE 5
WINTERKILL INDICATOR MODEL RESULTS